What is Landfill Gas?
Landfill Gas (LFG) is the product of microbiological decomposition of land-filled garbage. The microbial bugs turn complex organic compounds in garbage into methane, carbon dioxide, and trace amounts of other compounds. LFG is approximately 50 to 55 percent methane and approximately 40 to 45 percent carbon dioxide. The balance is made up of other compounds, including nitrogen and oxygen. Approximately 0.2 to 0.5 percent of LFG is composed of complex organic compounds that are not degraded by the bugs. A small percentage of LFG is composed of hydrogen sulfide and other sulfur compounds.

What compounds are commonly found in LFG?
LFG is made up of a combination of various compounds including:
- Methane (odorless) - Methane is nonreactive and not harmful to human health, and is a flammable gas. When present in select concentrations (5 to 15 percent by volume) it can potentially be explosive.
- Carbon Dioxide (everywhere) - The human lung transforms oxygen, inhaled in each breath, into carbon dioxide (CO2); which is exhaled. Plants “inhale” CO2 and “exhale” oxygen.

If methane and CO2 are odorless, then which compounds contribute to odor?
- Since the odorless gases, carbon dioxide and methane, are produced in large quantities, these gases carry the other LFGs in low concentrations. These other gases are what give the LFG its unpleasant odor and may include:
  - Mercaptans, Hydrogen Sulfide, and other Sulfur Compounds - Mercaptans and Hydrogen sulfide (H2S) have an odor normally associated with rotten eggs/rotten garbage. These sulfur compounds have a very low odor threshold, which means that the human nose can detect them at concentrations as low as 0.5 to 1 part per billion (ppb) or 0.000000001 percent by volume.
  - Non-Methane Organic Compounds (NMOC), or complex organic compounds, are compounds with more than one carbon atom. These compounds also have hydrogen atoms and could have oxygen, sulfur, chlorine, and nitrogen atoms as well. Generally, NMOCs are volatile and can have a cleaning solvent-type odor. NMOCs are found in several every-day items such as gasoline. Organic compounds are sources of energy for people, animals, microorganisms, and industry.

How long does it take before appreciable amounts of LFG begin to generate in a landfill?
Appreciable amounts of LFG begin to generate into landfill in approximately one to three years, depending on the type of garbage, amount of moisture, and other factors. Peak production of LFG is 5 to 7 years after the garbage was dumped.

Where does LFG come from?
Garbage contains many organic (carbon-based) compounds. Micro-organisms (bugs), which are found everywhere (air, water, soil, etc.), feed on organic compounds. Using water from rain or other molecules and nutrients, found in the soil or garbage (oxygen, nitrogen, sulfur, phosphorus, etc.), the bugs degrade complex organic compounds to form methane (the simplest of all organic compounds) and carbon dioxide.

How does LFG migrate?
When LFG is formed in a landfill, the vapors do not stay where they were formed; instead, they move around, taking the path of least resistance. This means the vapor particles move most easily when there are large open spaces for them to move through. As the LFG molecules are microscopic, an open space as big as a few grains of sand would be relatively large. LFG molecules can move laterally through the landfill, or they can move up and down in the landfill, depending on where the path of least resistance is. LFG can also escape through the top of the landfill into ambient air. Like vapor particles, which constantly move around randomly, LFG also follows the
How do weather events affect LFG release and odor problems?

- **Low pressure days:** When the vapor pressure of the ambient air and the atmosphere is lower than the pressure of the gases inside the landfill, more LFG will seep out of the landfill into the air. This release of gas is because the vapors are trying to equilibrate the pressures, moving from areas of high pressure to areas of low pressure. Low pressure days are cloudy and rainy.

- **Atmospheric Stability (wind and sun):**
  The atmosphere is considered stable when the number and speed of moving vapor particles is very low. Obviously, wind makes the atmosphere unstable. Sunlight also makes the atmosphere unstable, due to the fact that when sunlight hits one packet of air molecules, the air pocket heats up. Since hot air rises, that pocket moves upward and then a cooler air pocket moves down to take its place. Sooner or later that cool packet will be heated and rise and another packet will move to take its place repeating the process.

- **Inversion Layer:** At some height in the atmosphere, there is a line (parallel to the ground) above which there is all cold air and below which there is all warm air. The warm air is trying to rise, and the cold air is trying to drop; however, these levels of air keep bumping into each other. This imaginary line parallel to the ground is called the inversion layer. Vapor particles and air pockets that are above the inversion layer cannot easily get below the layer, and vice versa. Usually the inversion layer is higher during the day and lower at night; depending on other weather conditions it can move around.

Any LFG or vapor odors that escape the landfill on a sunny and windy day (atmosphere unstable) won’t hang around for very long. However, when there is no sun and no wind, the vapors and odors linger around the landfill. If the inversion layer is low, then the vapors and odors being emitted from the landfill are trapped between the inversion layer and the ground. Therefore, suppose the same amount of gas is emitted from the landfill on a Monday and on a Tuesday. If it is sunny and windy on Monday, and cloudy with a low inversion layer on Tuesday, then Tuesday will smell much worse.

How does a landfill cover system control LFG?

On a daily basis (or more frequently, if warranted) the garbage and solid waste that is disposed of at a landfill must be covered with material to control odors, disease, fires, blowing litter, and scavenging animals such as rats and seagulls.

The less porous the daily cover material, the less likely it is that odors from recently deposited garbage will be detectable. As broad generalization, a good cover requires a mixture of different sized particles to make the cover less porous and better at trapping the odors inside the landfill. The Natural Resources and Environmental Protection Act (NREPA), 1994 PA 451 (as amended), requires that a minimum of 6-inches of earthen material is placed as a daily cover.

NREPA includes the opportunity for landfill management to propose Alternative Daily Covers (ADC) that will provide equivalent or superior performance to the 6-inches of earthen material. ADC materials vary by site and must be approved by the State of Michigan Department of Environmental Quality (DEQ) before use on site. Common ADC materials include woodchips, foundry sands, contaminated soils, and manufactured materials such as geosynthetic materials, or spray-on mineral mortar coatings.

When a section of a landfill is closed permanently, it is normally covered with a series of materials: dirt, gravel, clay, synthetic materials, durable plastic liners, etc. Finally, vegetation is planted on the top of the landfill. The vegetation serves two purposes: 1) aesthetics, and 2) helps to hold the cover materials in place and provide erosion control. A typical landfill cover system in Michigan has: 1) 18-inches of clay at the bottom; 2) a plastic liner in the middle; 3) 2-feet of protective soil; 4) at least 6-inches of topsoil to support native shallow rooted vegetation.

If nothing further were done, gaseous molecules of LFG created by the microorganisms would slowly seep out of the landfill into the ambient air, taking the path of least resistance, by making their way in between the soil, clay, and plastic liner, to the surface.
How is LFG collected?

Typically, LFG is collected using a system of wells or trenches. These wells or trenches are connected, through piping, to a large industrial fan or other vapor moving unit which maintains a negative pressure on the whole gas collection system. Negative pressure means that the fan is always pulling gases out of the system, never pushing gases into the system. In this way, LFG is vacuumed out of the landfill.

To install a well, one must drill deep into the landfill trash mound and insert a long section of perforated vertical pipe. Each well has its own pressure regulator on it, so that the force of the vacuum can be controlled at each individual well; this is important. The reason for this is if the vacuum pressure were too great, then not only LFG would be collected, but air would be sucked into the landfill from the ambient air above the landfill. If the pressure at a certain well was too low, then it would not collect all of the LFG and some of the LFG would seep out of the landfill cover surface.

It is important to note that increasing the pressure at each well, in an attempt to maximize gas collection, is not a viable option. As previously noted, too great a pressure at a gas well increases the potential for ambient air to be sucked into the landfill. Excessive amounts of oxygen within the degrading waste mass can provide the ideal condition for a subsurface landfill fire. To address this concern, federal regulations dictate that a gas well must maintain less than 5 percent oxygen by volume. Therefore, the pressure at each well must be different, based on the depth of the trash, the density of the trash, the age of the trash, and the amount of the monitored LFG components (oxygen, methane, and carbon dioxide).

Trenches are sections of pipe that are laid horizontally in the landfill, and function in a manner similar to wells.
What happens to LFG after it is collected?
Once the LFG is collected using the wells, trenches, and fans, it is usually channeled to some sort of control device. The control device is typically a combustion device or a LFG to energy plant.

Methane, is still a source of energy, although the simplest organic compound. One molecule of methane does not release as much heat and energy as one molecule of an NMOC, but it is still useful. Therefore, LFG (usually 50 to 55 percent methane) is often channeled to a turbine or other unit for the production of electricity, heat, or power. The Internal Revenue Service offers tax credits to companies that burn LFG for energy.

The combustion of methane (or other organic compounds) results in carbon dioxide, carbon monoxide, and water as the primary products. Many other compounds in LFG (complex sulfur compounds and NMOCs) are also destroyed in the combustion process, eliminating many of the odors associated with LFG. If the use of methane energy in LFG is not feasible for whatever reason(s), the LFG is often combusted in an open or enclosed flare. Flare combustion of LFG undergoes the same process as that listed above; however, the energy resulting from the combustion is not recovered for use.

Questions?
For more information on landfill gas call your District Office of Waste Management and Radiological Protection or Air Quality Division at the Department of Environmental Quality.

The Department of Environmental Quality, Kalamazoo District Office can be reached at (269) 567-3500.

This document was prepared from United States Environmental Protection Agency, January 2000, Facts About Landfill Gas Informational Flyer.

Additional resources: